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USE of OZONE in TOMATO RIPENING ROOMS

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By Earl D. Mallison and Donald H. Spalding 1/

SUMMARY

Tomatoes packed in fiberboard boxes were ripened in commercial ripening rooms at 65° F., 80 to 95 percent relative humidity, with and without 0.02 to 0.04 parts per million (p.p.m.) ozone.

Losses caused by such factors as overripeness, shoulder scars, bruising, sunburn, and decay were about the same in treated and untreated lots. Ozone did not reduce decay of tomatoes artificially inoculated with the watery sour rot fungus (Geotrichum candidum Lk. ex. Pers.). Ozone had no significant effect on the rate of ripening. The ozone level inside the fiberboard tomato containers was approximately 10 percent of that outside the container. The cost of using ozone was about $3.30 a week for one ripening room, or about 8 cents per ton of tomatoes.

INTRODUCTION

Ozone is being used in some tomato ripening rooms in an effort to reduce losses caused by decay.

Ozone, an oxidizing gas, is an unstable product which breaks down or decomposes readily to oxygen. It is "also decomposed by catalysts, including water vapor and many surfaces." 2/ Surfaces in tomato ripening rooms include the walls, floors, and ceilings, the skin of tomatoes, and the outer surfaces of tomato boxes. Tops, bottoms, and sides of the tomato boxes could cause the ozone to change to oxygen before it reaches the tomatoes inside the boxes and prevent any beneficial effect in retarding decay of ripening of tomatoes.

High concentrations of ozone are toxic to humans even when exposed for a short period of time. In the normal course of a working day, workers would be in a ripening room for short periods of time to place or remove tomatoes. This restricts concentrations used in ripening rooms to those considered safe to humans. The Threshold Limit Value of ozone is 0.1 parts per million by volume (p.p.m./vol.). 3/ This represents the concentration of ozone under which it is

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1/ Agricultural marketing specialist, Transportation and Facilities Research Division and research plant pathologist, Market Quality Research Division, respectively, Agricultural Research Service.

2/ Ewell, A. W. Ozone and Light: II. Ozone. In Amer. Soc. Refrig. Engin., The Refrigeration Data Book; Refrigeration Application Volume, Ed. 2, Sec. II. Cold Storage Practice. Chap. 18, pp. 196-199. Menasha, Wis. 1946.

3/ Threshold Limit Values for 1965. Adopted at the 27th Annual Meeting of the American Conference of Governmental Hygienists, Houston, Tex., May 2-4, 1965.

believed that nearly all workers may be repeatedly exposed, day after day, without adverse effects.

This study was conducted to find out whether exposing tomatoes to ozone in ripening rooms would reduce waste and spoilage and significantly slow the ripening of tomatoes and to determine the cost of using ozone in tomato ripening rooms under commercial conditions. The tests were made in a commercial repacking plant located in northern New Jersey.

PROCEDURES

Tests were made in two commercial ripening rooms (20 by 40 by 16 feet) comparable in every respect except that one had ozone added and the other one did not. The temperature of each room was thermostatically controlled at 65° ± 2° F. The relative humidity in each room was maintained between 80 and 95 percent by manually operating a humidifier suspended from the center of the ceiling. Readings were taken at frequent intervals so that temperature and humidity in the two chambers were kept as near the same as possible.

Ozone was generated by two Suncap Model XR units (0.8 amperes, 115 volts) supplied by Suncap Systems, Inc., 4/ Philadelphia, Pa. The ozonators were operated from outside the chamber where the high humidity of the air in the ripening room would not affect the efficiency of ozone production. The units were located just below ceiling level at diagonally opposite corners of the room. Ozone was blown into the room through tubes in the walls. The level of ozone was adjusted to maintain a concentration between 0.02 and 0.05 p.p.m./vol., as continuously measured with a Mast Model 725-6 portable ozone meter and recorder (Mast Development Co., Davenport, Iowa).

Decay and Shrinkage Studies

Two studies were made to determine the effect of ozone on decay of tomatoes during ripening.. In the first study, equal lots of tomatoes were placed in the two ripening rooms for 6 to 8 days and then examined for decay.

The tomatoes used in the tests were grown, graded, and packed by the same shipper in the vicinity of Geneva, N.Y., transported by truck to Jersey City, N.J., and unloaded September 17, 20, 21, and 23, 1965. Part-telescope fiberboard boxes, with "H" dividers, holding 40 pounds net, were used for shipping and also as ripening room containers. The tomatoes were harvested when mature green. When they were placed in the ripening rooms, between 10 and 23 percent were breakers 5/ (showing slight yellowing at the blossom end).

4/ Use of manufacturers' names in this report does not constitute endorsement by the U.S. Department of Agriculture of their products or imply discrimination against similar products made by other manufacturers.

5/ Color definitions of tomatoes, as used in this report, are: Green, surface completely green; breakers, definite break from green to tannish yellow; pink, over 50 percent of surface is pink; and ripe, over 75 percent of surface is red.

One hundred and forty boxes were selected at random from each of 4 shipments, with 35 boxes stacked on each of 4 pallets. Two pallets from each shipment were placed in the ripening room containing ozone, and two pallets were held as controls in the ripening room without ozone. The eight pallets in each room occupied less than 20 percent of the available floor space. The rest of the room was left vacant. The door was kept closed and a large fan was operated continuously during the test to maintain uniform temperature, relative humidity, and concentration of ozone.

The tomatoes were removed from the ripening rooms when 50 percent or more were ready to pack. Net weight of tomatoes in each pallet was obtained before the pallets were placed in ripening rooms and when they were removed. Tomatoes were run over a sorting belt where workers removed those unsuitable for packing in over-wrapped trays. Those showing decay were placed in one receptacle and those that were over-mature or damaged from bruises and cuts were placed in another receptable. All rejected tomatoes were weighed.

In the second study, tomatoes were inoculated with the watery sour rot fungus (Geotrichum candidum Lk. ex. Pers.). The skin of individual tomatoes was punctured to a depth of 2 millimeters with 5 pins mounted in a cork. The punctured area was immersed in a water solution containing a heavy suspension of watery soft rot spores. The inoculated tomatoes then were air dried, divided into two equal lots, and packed in fiberboard boxes. Two tests were made.

The first test was with 600 mature-green tomatoes. The tomatoes were placed in the two ripening rooms immediately after inoculation and were inspected for decay at the end of 7 days.

The second test was with 440 inoculated pink tomatoes. These tomatoes were held at room temperature for 6 hours before being placed in the ripening rooms and were examined after 4 days in the ripening rooms.

Ripening Studies

The effect of ozone on the rate of ripening of tomatoes was studied on the same four lots of tomatoes as were used in the first decay study. After the tomatoes were removed from the ripening rooms, and decayed, over-mature, or damaged tomatoes were removed from the lots, the remaining tomatoes were run over an electronic color sorting machine that separated them into greens, breakers, pinks, and ripes.

Air samples in the ripening rooms were collected periodically in Thunberg tubes of 52-milliliter capacity for ethylene analysis. The air was withdrawn from the tube with a 50-ml. syringe to obtain a vacuum. An air sample was taken from the central area of the room by opening the sidearm of the Thunberg tube. The sampling procedure was repeated to insure a representative sample. The tubes were taped to hold the cap in place until the samples could be analyzed for ethylene on gas chromatograph equipment, using procedures described previously. 6/

Concentration of Ozone in Boxes

A continuous record of concentration of ozone inside empty boxes and boxes filled with tomatoes was made. Air samples from the center of two boxes filled with tomatoes were drawn into an ozone meter through a short plastic tube. The ozone meter was placed in two empty boxes for a few hours. The covers of the boxes were on and the boxes were isolated so none of the openings would be blocked by other containers.

RESULTS AND DISCUSSION

Decay and Shrinkage

Decay averaged 1.2 percent in the eight pallet loads of tomatoes ripened in the room without ozone and 0.9 percent in those in the room with ozone (table 1). The difference is not statistically significant. Total waste, including moisture losses, amounted to about 6 percent of the tomatoes in each room.

Loss of weight (moisture loss) during 6, 7, and 8 days in the ripening rooms averaged 1.0 percent for the control test lots and 1.1 percent for the tomatoes ripened in the room containing ozone (table 1). This difference also is not statistically significant.

In the test of mature-green tomatoes inoculated with the sour rot fungus, only 1 out of 600 tomatoes decayed after holding 7 days in ripening rooms with and without ozone.

Of the inoculated pink tomatoes, an average of 17 percent of those held in the room with ozone were decayed and 19.5 percent of those held in the control room were decayed. This difference is not statistically significant.

The tissue surrounding the puncture wounds not showing decay dried some during the holding period. Appearance and degree of drying were about the same for all lots.

Rate of Ripening

Two pallet loads of tomatoes were removed from each of the two ripening rooms at the same time, when over 50 percent of the tomatoes were ripe enough to package in overwrap trays. This procedure is routine in the prepackaging plant used in the study. An average of 59.5 percent of the tomatoes in the

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6/ Spalding, D. H., and M. Lieberman. Factors affecting the production of ethylene by *Penicillium digitatum*. Plant Physiol. 40: 645-648. 1965.

Table 1.-- Moisture and waste losses during storage of comparable lots of tomatoes ripened in rooms without and with ozone 1/

Room and lot number	Storage time	Initial weight	Weight loss caused by--			Total weight loss
			Loss of moisture	Decay	Other 2/	
	Days	Pounds	Pounds	Pounds	Pounds	Pounds
No ozone:						
1	7	2,856	33	47	105	185
2	7	2,864	26	52	135	213
3	8	2,872	33	18	80	131
4	6	2,889	21	15	77	113
Total	--	11,481	113	132	397	642
Percent	--	--	1.0	1.2	3.4	5.6
With ozone:						
1	7	2,871	36	42	147	225
2	7	2,883	34	35	141	210
3	8	2,876	35	16	81	132
4	6	2,839	22	12	79	113
Total	--	11,469	127	105	448	680
Percent	--	--	1.1	0.9	3.9	5.9

1/ Differences between treatments are not statistically significant at 5-percent level.

2/ Overripe, shoulder scars and damaged from bruises and cuts.

four lots (table 2) were at the ripe stage and 13.8 percent were at the pink stage when removed from the control room, while 52.2 percent were at the ripe stage and 12.4 percent were at the pink stage when removed from the room containing ozone. These differences were not statistically significant.

Ethylene is a well-known ripening agent used commercially in ripening bananas and other fruits and is given off by fresh fruit during ripening. The data (table 3) show that ethylene concentrations in the ozone room were, with one exception, from one-half to two-thirds those in the control room. Gane 7/ found that ozone would oxidize ethylene evolved from ripening bananas which

7/ Gane, R. Respiration of bananas in the presence of ethylene. New Phytologist 36: 170-178. 1936.

Table 2.-- Stage of ripeness of comparable lots of tomatoes after storage in ripening rooms without and with ozone 1/

Room and lot number	Storage time	Ripe	Pink	Breakers	Green	Total
	Days	Pounds	Pounds	Pounds	Pounds	Pounds
No ozone:						
1	7	2,002	282	228	139	2,671
2	7	1,034	393	673	551	2,651
3	8	2,185	291	199	66	2,741
4	6	1,223	521	594	438	2,776
Total		6,464	1,487	1,694	1,194	10,839
Percent		59.5	13.8	15.7	11.0	100
With ozone:						
1	7	2,025	277	152	192	2,646
2	7	1,026	226	712	709	2,673
3	8	1,741	480	334	189	2,744
4	6	852	358	1,020	518	2,748
Total		5,644	1,341	2,218	1,608	10,811
Percent		52.2	12.4	20.5	14.9	100

1/ Differences in each of the four stages of ripeness between treatments are not statistically significant at 5-percent level.

Table 3.-- Ethylene concentrations in tomato ripening rooms with and without ozone

Date	Ethylene	
	With ozone	Without ozone
	p.p.m.	p.p.m.
Sept. 22	0.18	0.36
Sept. 23	.18	.42
Sept. 24	.48	.48
Sept. 27	.48	1.51
Sept. 28	.42	1.18
Sept. 29	.61	1.82

explains the lower concentrations commonly found in the ozone room. Earlier tests 8/ made in the same ripening rooms to measure the concentrations of ethylene when filled to capacity with ripening tomatoes show that the maximum concentrations of 6.0 to 7.5 p.p.m. were not enough to be of material use in the commercial ripening of tomatoes.

Concentration of Ozone Inside Tomato Boxes

The part-telescope boxes used as shipping containers and as ripening room containers have limited access for ventilation. Each box has 2 hand holes and a total of 12 slots (each 3 by 0.5 inches) in sides and ends. Tomatoes pressing into these openings and a close contact of boxes stacked on pallets decrease the possibilities of ozone entering the containers and coming in contact with the tomatoes. In addition, ozone is decomposed when it contacts surfaces such as the outer surfaces of fiberboard boxes.

A comparison of the concentrations of ozone in the air in the ripening room and inside the empty and filled boxes suggests that the corrugated fiberboard boxes keep the ozone from reaching the contents. When the concentration of ozone in the air of the ripening room was 0.028 p.p.m./vol., the concentration inside an empty box was 0.006 p.p.m./vol., 78.6 percent less. When the ozone concentration was 0.028 p.p.m./vol. outside the box, it was only 0.003 p.p.m./vol. inside the box filled with tomatoes, 89.3 percent less.

The low concentration of ozone inside the tomato boxes could in part be responsible for the lack of significant differences in the percent decay found in comparable lots of tomatoes held 6 to 8 days in ripening rooms with and without ozone.

COST OF OZONE

The cost of producing ozone used in this study is based on a 20- by 40-foot ripening room for a period of 1 week--the approximate time needed to ripen a lot of mature-green tomatoes. The room would hold approximately 20 tons of tomatoes when the pallets are single-stacked and 40 tons when the pallets are double-stacked.

The two ozone generators used in this study cost $1,200 installed. Based on an estimated life of 10 years, the average depreciation is $2.30 per week.

Estimated time to clean and maintain two generators is 1 hour per month. At $3 an hour for labor, the average cost is $0.70 a week.

The cost of electric power needed to operate the ozone generators will vary with local rates and the total amount of electric power used in the plant. Each generator is rated as using 100 to 125 watts per hour. The cost of power at the time this study was made is estimated at $2.60 per horsepower per month.

8/ Radspinner, W. A. Commercial aspects of ripening mature-green tomatoes with ethylene gas. Pre-Pack-Age 8 (4): 1-4. Dec. 1954.

Calculated cost of electric power used in operating both generators is 30 cents per week.

Estimated total cost of operating two generators for one week is $3.30 and the cost per ton is between 8 and 16 cents depending on the amount of tomatoes in the ripening room.

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